

WHAT IS CLAIMED IS:

1                   1.       A hearing aid, comprising:  
2                   an input signal channel providing digital input signals;  
3                   a signal path adapted to process said digital input signals in accordance  
4 with a predetermined signal processing algorithm to produce a digital output signal,  
5 wherein said signal path further comprises at least one signal processing function  
6 operating on a warped frequency scale; and  
7                   an output conversion means adapted to convert said output signals to an  
8 audio output.

1                   2.       The hearing aid of claim 1, wherein said at least one signal  
2 processing function further comprises a plurality of cascaded all-pass filters.

1                   3.       The hearing aid of claim 1, wherein said warped frequency scale  
2 approximates a Bark scale.

1                   4.       A dynamic range compressor, comprising:  
2                   an input signal channel providing digital input signals;  
3                   a plurality of cascaded all-pass filters, wherein said digital input signals  
4 pass through said plurality of cascaded all-pass filters, and wherein said plurality of  
5 cascaded all-pass filters output a sequence of delayed samples;  
6                   means for applying a frequency domain transform on said sequence of  
7 delayed samples, wherein a warped sequence results from said frequency domain  
8 transform applying means;  
9                   means for calculating a plurality of frequency domain level estimates from  
10 said warped sequence;  
11                  means for calculating a plurality of frequency domain gain coefficients  
12 from said plurality of frequency domain level estimates;  
13                  means for applying an inverse frequency domain transform on said  
14 plurality of frequency domain gain coefficients, wherein a set of compression filter  
15 coefficients of a compression gain filter result from said inverse frequency domain  
16 transform applying means; and

17 means for convolving said sequence of delayed samples with said set of  
18 compression filter coefficients to produce a digital output signal.

1 5. The dynamic range compressor of claim 4, further comprising a  
2 hearing aid, wherein the dynamic range compressor is incorporated within said hearing  
3 aid.

1 6. The dynamic range compressor of claim 4, wherein said plurality  
2 of frequency domain gain coefficients comprise a warped time-domain filter.

1 7. The dynamic range compressor of claim 4, further comprising  
2 means for windowing said sequence of delayed samples, wherein a windowed sequence  
3 of delayed samples results from said windowing means, and wherein said warped  
4 sequence results from applying said frequency domain transform to said windowed  
5 sequence of delayed samples.

1 8. The dynamic range compressor of claim 4, further comprising a  
2 digital-to-analog converter, said digital-to-analog converter converting said digital output  
3 signals to analog output signals.

1 9. The dynamic range compressor of claim 8, further comprising an  
2 output transducer, said output transducer converting said analog output signals to an  
3 audio output.

1 A 10. The dynamic range compressor of claim 4, said plurality of  
2 cascaded all-pass filters comprising a plurality of first order all-pass filters.

1 11. The dynamic range compressor of claim 4, said sequence of  
2 delayed samples comprising 16 samples.

1 12. The dynamic range compressor of claim 4, further comprising a  
2 digital processor, wherein said digital processor is adapted to provide said frequency  
3 domain transform applying means, said frequency domain level estimates calculating  
4 means, said frequency domain gain coefficients calculating means, said inverse frequency  
5 domain transform applying means, and said means for convolving said sequence of  
6 delayed samples.

1 13. The dynamic range compressor of claim 12, wherein said digital  
2 processor comprises a software programmable digital signal processor.

1 14. The dynamic range compressor of claim 4, wherein said frequency  
2 domain transform applying means uses a transform selected from the group consisting of  
3 discrete Fourier transforms, fast Fourier transforms, Goertzel transforms, and discrete  
4 cosine transforms.

1 15. The dynamic range compressor of claim 4, further comprising:  
2 an input transducer, said input transducer converting audio input signals to  
3 analog input signals; and  
4 an analog-to-digital converter, said analog-to-digital converter converting  
5 said analog input signals to said digital input signals.

1 16. The dynamic range compressor of claim 4, further comprising:  
2 a digital-to-analog converter, said digital-to-analog converter converting  
3 said digital output signals to analog output signals; and  
4 an output transducer, said output transducer converting said analog output  
5 signals to an audio output.

1 17. A dynamic range compressor, comprising:  
2 an input signal channel providing digital input signals;  
3 an input data buffer, said input data buffer holding at least one block of  
4 data comprised of a portion of said digital input signals;  
5 a plurality of cascaded all-pass filters, wherein a first block of said digital  
6 input signals pass from said input data buffer through said plurality of cascaded all-pass  
7 filters, and wherein said plurality of cascaded all-pass filters output a first sequence of  
8 delayed samples;  
9 means for windowing a first portion of said first sequence of delayed  
10 samples, wherein a first windowed sequence of delayed samples results from said  
11 windowing means;  
12 means for applying a first frequency domain transform on said first  
13 windowed sequence of delayed samples, wherein a first warped sequence results from  
14 said first frequency domain transform applying means;

means for calculating a first plurality of frequency domain level estimates of said first warped sequence;

means for windowing a second portion of said first sequence of delayed samples, wherein a second windowed sequence of delayed samples results from said windowing means;

means for applying a second frequency domain transform on said second windowed sequence of delayed samples, wherein a second warped sequence results from said second frequency domain transform applying means;

means for calculating a second plurality of frequency domain level estimates of said second warped sequence;

means for summing said first and second plurality of frequency domain level estimates, wherein a summed first and second plurality of frequency domain level estimates results from said summing means;

means for normalizing said summed first and second plurality of frequency domain level estimates, wherein a normalized first and second plurality of frequency domain level estimates results from said normalizing means;

means for calculating a plurality of frequency domain gain coefficients from said normalized first and second plurality of frequency domain level estimates;

means for applying an inverse frequency domain transform on said plurality of frequency domain gain coefficients, wherein a set of compression filter coefficients of a compression gain filter result from said inverse frequency domain transform applying means;

means for convolving a second sequence of delayed samples with said compression filter coefficients, said second sequence of delayed samples produced by a second block of said digital input signals passing from said input data buffer through said plurality of cascaded all-pass filters, wherein a digital output signal results from said convolving means.

18. The dynamic range compressor of claim 17, further comprising a hearing aid, wherein the dynamic range compressor is incorporated within said hearing aid.

19. The dynamic range compressor of claim 17, wherein said plurality of frequency domain gain coefficients comprise a warped time-domain filter.

1           20.     The dynamic range compressor of claim 17, further comprising a  
2 digital-to-analog converter, said digital-to-analog converter converting said digital output  
3 signals to analog output signals.

1           21.     The dynamic range compressor of claim 20, further comprising an  
2 output transducer, said output transducer converting said analog output signals to an  
3 audio output.

1           22.     The dynamic range compressor of claim 17, said plurality of  
2 cascaded all-pass filters comprising a plurality of first order all-pass filters.

1           23.     The dynamic range compressor of claim 17, further comprising a  
2 digital processor, wherein said digital processor is adapted to provide said windowing  
3 means, said means for applying said first and second frequency domain transforms, said  
4 means for calculating said first and second plurality of frequency domain level estimates,  
5 said summing means, said normalizing means, said frequency domain gain coefficients  
6 calculating means, said inverse frequency domain transform applying means, and said  
7 convolving means.

1           24.     The dynamic range compressor of claim 17, wherein said means  
2 for applying said first and second frequency domain transforms use a transform selected  
3 from the group consisting of discrete Fourier transforms, fast Fourier transforms, Goertzel  
4 transforms, and discrete cosine transforms.

1           25.     The dynamic range compressor of claim 17, further comprising:  
2 an input transducer, said input transducer converting audio input signals to  
3 analog input signals; and  
4 an analog-to-digital converter, said analog-to-digital converter converting  
5 said analog input signals to said digital input signals.

1           26.     The dynamic range compressor of claim 17, further comprising:  
2 a digital-to-analog converter, said digital-to-analog converter converting  
3 said digital output signals to analog output signals; and  
4 an output transducer, said output transducer converting said analog output  
5 signals to an audio output.

1 27. The hearing aid of claim 17, wherein said windowing means  
2 provides a 50 percent overlap of said first and second pluralities of frequency domain  
3 level estimates.

1 28. The hearing aid of claim 17, wherein a quantity of samples  
2 corresponding to said first block of said digital input signals is equivalent to a quantity of  
3 first order all-pass filters corresponding to said plurality of cascaded all-pass filters.

1 29. The hearing aid of claim 28, wherein said first portion of said first  
2 sequence of delayed samples is comprised of a first half of said first sequence of delayed  
3 samples and said second portion of said first sequence of delayed samples is comprised of  
4 a second half of said first sequence of delayed samples.

1 30. A hearing aid, comprising:  
2 an input signal channel providing digital input signals;  
3 an input data buffer, said input data buffer holding a block of data of size  
4 M comprised of a portion of said digital input signals;  
5 a plurality of cascaded all-pass filters comprised of 2M cascaded all-pass  
6 filters, wherein a first block of said digital input signals pass from said input data buffer  
7 through said plurality of cascaded all-pass filters to form a first sequence of delayed  
8 samples and wherein a second block of said digital input signals pass from said input data  
9 buffer through said plurality of cascaded all-pass filters to form a second sequence of  
10 delayed samples, and wherein said first sequence of delayed samples and said second  
11 sequence of delayed samples form a combined sequence of delayed samples;  
12 means for windowing a first portion of said combined sequence of delayed  
13 samples, wherein said first portion is of size M, wherein a windowed sequence of delayed  
14 samples results from said windowing means;  
15 means for applying a 2M-point frequency domain transform on said  
16 windowed sequence of delayed samples, wherein a warped sequence results from said  
17 frequency domain transform applying means;  
18 means for calculating a plurality of frequency domain level estimates of  
19 said warped sequence;  
20 means for calculating a plurality of frequency domain gain coefficients  
21 from said plurality of frequency domain level estimates;

22 means for applying an inverse frequency domain transform on said  
23 plurality of frequency domain gain coefficients, wherein a set of compression filter  
24 coefficients of a compression gain filter result from said inverse frequency domain  
25 transform applying means; and  
26 means for convolving a second portion of said combined sequence of  
27 delayed samples with said compression filter coefficients, wherein said second portion is  
28 of size M, wherein a digital output signal results from said convolving means.

1 31. The dynamic range compressor of claim 30, further comprising a  
2 hearing aid, wherein the dynamic range compressor is incorporated within said hearing  
3 aid.

1 32. The dynamic range compressor of claim 30, wherein said plurality  
2 of frequency domain gain coefficients comprise a warped time-domain filter.

1 33. The dynamic range compressor of claim 30, further comprising a  
2 digital-to-analog converter, said digital-to-analog converter converting said digital output  
3 signals to analog output signals.

1 34. The dynamic range compressor of claim 33, further comprising an  
2 output transducer, said output transducer converting said analog output signals to an  
3 audio output.

1 35. The dynamic range compressor of claim 30, said plurality of  
2 cascaded all-pass filters comprising a plurality of first order all-pass filters.

1 36. The dynamic range compressor of claim 30, further comprising a  
2 digital processor, wherein said digital processor is adapted to provide said windowing  
3 means, said means for applying said 2M-point frequency domain transform, said means  
4 for calculating said plurality of frequency domain level estimates, said frequency domain  
5 gain coefficients calculating means, said inverse frequency domain transform applying  
6 means, and said convolving means.

1 37. The dynamic range compressor of claim 30, wherein said means  
2 for applying said frequency domain transform uses a transform selected from the group

3 consisting of discrete Fourier transforms, fast Fourier transforms, Goertzel transforms,  
4 and discrete cosine transforms.

1 38. The dynamic range compressor of claim 30, further comprising:  
2 an input transducer, said input transducer converting audio input signals to  
3 analog input signals; and  
4 an analog-to-digital converter, said analog-to-digital converter converting  
5 said analog input signals to said digital input signals.

1 39. The dynamic range compressor of claim 30, further comprising:  
2 a digital-to-analog converter, said digital-to-analog converter converting  
3 said digital output signals to analog output signals; and  
4 an output transducer, said output transducer converting said analog output  
5 signals to an audio output.

1 40. A method of processing sound in a hearing aid, comprising the  
2 steps of:  
3 receiving digital input signals;  
4 passing a portion of said digital input signals through a plurality of  
5 cascaded all-pass filters to form a sequence of delayed samples;  
6 windowing said sequence of delayed samples;  
7 applying a frequency domain transform to said windowed sequence of  
8 delayed samples to form a warped sequence;  
9 calculating a plurality of frequency domain level estimates from said  
10 warped sequence;  
11 calculating a plurality of frequency domain gain coefficients from said  
12 plurality of frequency domain level estimates to form a warped time domain filter;  
13 applying an inverse frequency domain transform on said plurality of  
14 frequency domain gain coefficients to form a set of compression filter coefficients; and  
15 convolving said sequence of delayed samples with said compression filter  
16 coefficients to form a digital output signal.